

Soil moisture and temperature assimilation into the GEOS-5 land surface model

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Outline

1. Continental-scale evaluation of remotely sensed soil moisture retrievals
 - ▶ Better understanding of observation uncertainty globally, leads to improved retrievals and enhanced use in assimilation
2. Assimilation of L-band microwave brightness temperatures
 - ▶ Improve model near-surface and root-zone soil moisture
3. Assimilation of geostationary skin temperature retrievals
 - ▶ Improve surface turbulent fluxes
 - ▶ Enhance assimilation of surface-sensitive radiances in GEOS-5 ADAS

1. Continental-scale evaluation of remotely sensed soil moisture retrievals

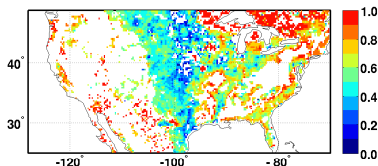
- ▶ Examine available methods for globally estimating Root Mean Square Errors (RMSE) in remotely sensed soil moisture
 - ▶ Difficulty: no recognized soil moisture truth over large domains
 - ▶ Test whether useful for evaluating novel data sets, specifying observation error covariances for DA
- ▶ Estimate RMSE over North America for ASCAT and X-band AMSR-E (LPRM) soil moisture data sets, for Jan 2007-Oct 2011

Draper et al (subm.), RSE

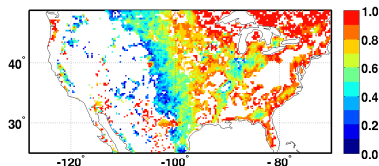
Triple collocation fRMSE (fRMSE^{TC})

- ▶ Triple collocation using ASCAT, AMSR-E, and Catchment near-surface soil moisture anomalies
(anomaly = deviation from the mean seasonal cycle)
- ▶ Present result as $\text{fRMSE}(X) = \text{RMSE}(X) / \text{stdev}(X)$

ASCAT fRMSE^{TC}



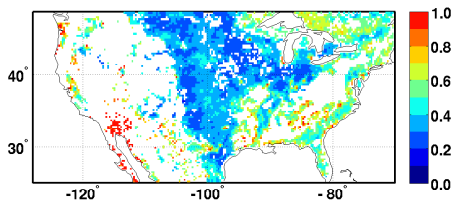
AMSR-E fRMSE^{TC}



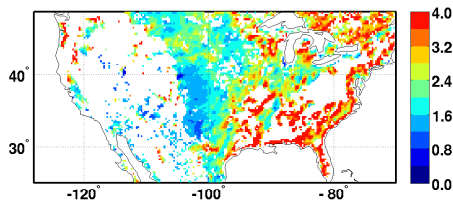
Error Propagation ($fRMSE^{EP}$)

- ▶ Error propagation (Naeimi et al, 2009; Parinussa et al, 2011) produces timeseries of RMSE in near-surface soil moisture anomalies
- ▶ Use mean of timeseries, present as $fRMSE$

ASCAT $fRMSE^{EP}$



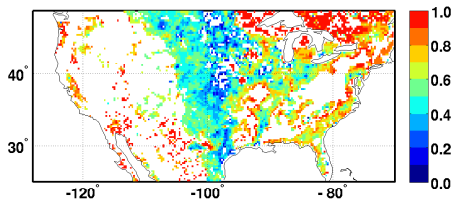
AMSR-E $fRMSE^{EP}$



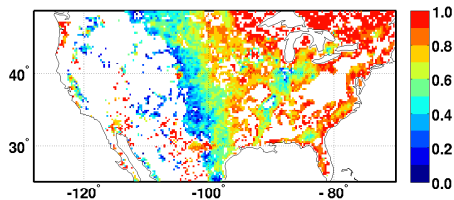
- ▶ Error propagation designed to detect (temporal/spatial) variation in errors, little confidence in magnitude

fRMSE^{TC} and fRMSE^{EP} maps

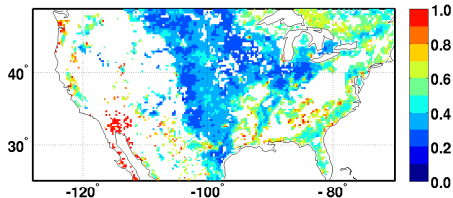
ASCAT fRMSE^{TC}



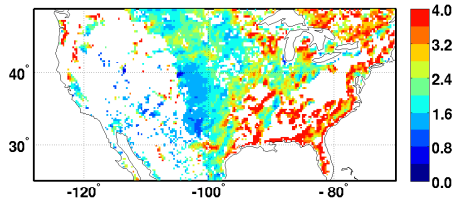
AMSR-E fRMSE^{TC}



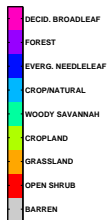
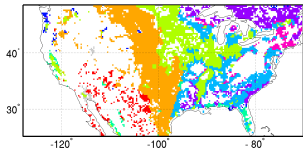
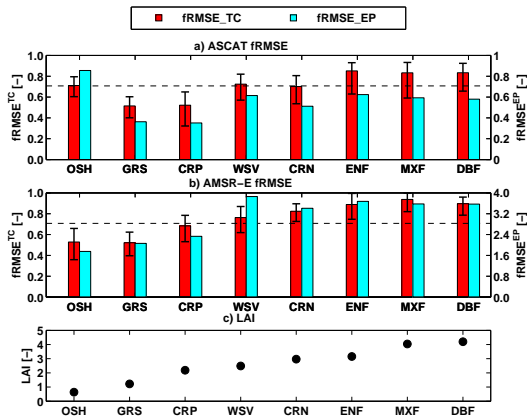
ASCAT fRMSE^{EP}



AMSR-E fRMSE^{EP}



fRMSE^{TC} and fRMSE^{EP} by land cover



- ▶ General agreement in spatial variation between fRMSE for each method
- ▶ For AMSR-E, fRMSE has stronger signal of vegetation cover

Soil moisture evaluation summary

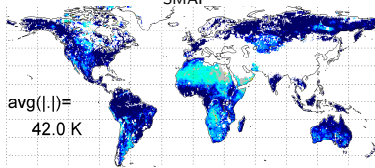
- ▶ Both triple collocation and error propagation can accurately detect spatial variability in ASCAT and AMSR-E fRMSE
- ▶ Triple collocation appears to be accurately detecting magnitude of fRMSE
- ▶ Both methods could be useful for evaluating remotely sensed soil moisture globally:
 - ▶ Evaluating novel remotely sensed soil moisture data sets
 - ▶ Specifying (spatially/temporally) variable observation error variances for use in data assimilation

2. Assimilation of L-band passive microwave brightness temperature observations

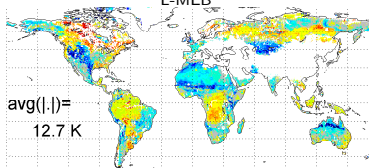
- ▶ Using brightness temperature from SMOS (launched by ESA in 2009) in preparation for SMAP (to be launched by NASA in 2014)
- ▶ Calibrate the microwave radiative transfer model (RTM) to remove long-term bias between Catchment model and L-band observations
- ▶ Updates to Catchment model soil parameters, for improved soil moisture/brightness temperature forecasts
- ▶ Preliminary results from assimilation of SMOS observations at SCAN sites in North America
 - ▶ Assimilate into Catchment model, forced with MERRA atmospheric fields, with gauge-corrected precipitation

Particle Swarm Optimization calibration of the RTM

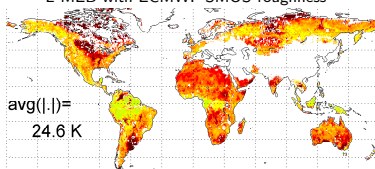
Mean (Catch./RTM - SMOS) T_b , Jul 2010 - June 2011 (H-pol, 42.5°, asc.)
SMAP



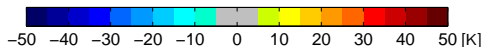
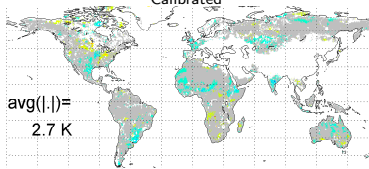
L-MEB



L-MEB with ECMWF-SMOS roughness



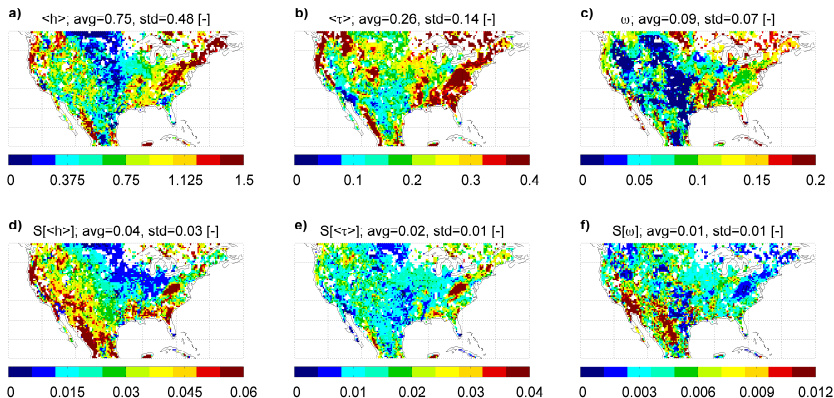
Calibrated



- Calibration (h, τ & ω) removes most long-term Catchment-SMOS biases

De Lannoy et al (2013), JHM

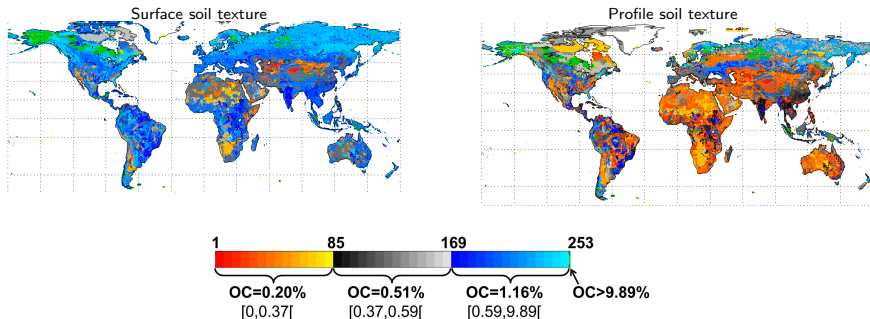
Markov Chain Monte Carlo optimization calibration of the RTM



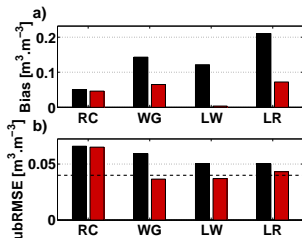
- Obtain similar parameter estimates with MCMC (Vrugt et al, 2008) as with PSO, uncertainty of estimated parameters is low

Updated Catchment soil parameters for SMAP L4_SM

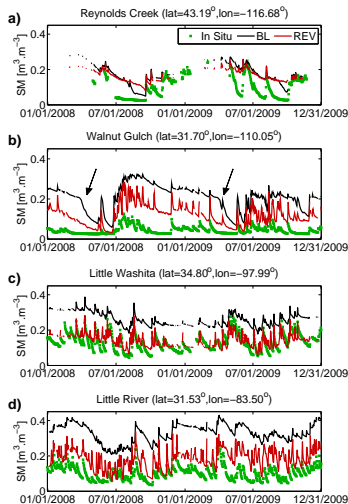
- ▶ New soil parameters: Woesten et al (2001) pedotransfer functions, and other updates
- ▶ New soil texture classes: composite NGDC, HWSD, STATSGO2 texture, including organic material



Updated Catchment soil parameters for SMAP L4_SM

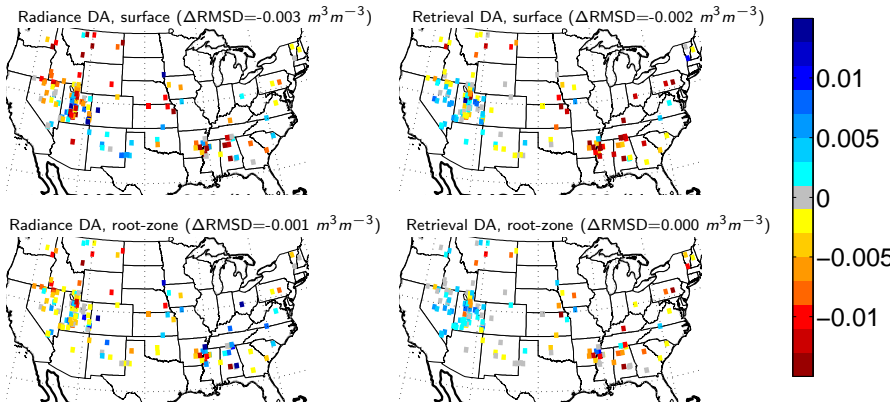


- Compared to ARS Watershed near-surface soil moisture observations, the updated parameters improve the soil moisture dry-down and reduce the biases



Assimilation of SMOS observations at SCAN sites

Change in unbiased RMSD ($m^3 m^{-3}$) with in situ SCAN soil moisture observations, from assimilation of SMOS observations (Apr 2010-Mar 2012)



► Similar results from radiance and retrieval assimilation (preliminary!)

L-band T_B assimilation summary

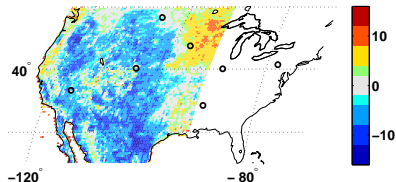
- ▶ Obtaining similar skill improvement from direct (brightness temperature) assimilation as from retrieval (soil moisture) assimilation
 - ▶ For direct assimilation, bias correction is very difficult
- ▶ Availability of remotely sensed soil moisture / brightness temperatures useful for better understanding/improving model performance

3. Assimilation of geostationary skin temperature retrievals

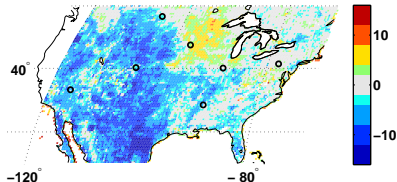
- ▶ New global high resolution T_{skin} product from geostationary satellites, provided by NASA Langley Research Center
 - ▶ Early results suggest comparable accuracy to MODIS T_{skin}
 - ▶ Currently available 3-hourly (cloud-free) at 0.25° resolution
- ▶ Assimilate GOES T_{skin} into the Catchment model, forced with MERRA atmospheric fields

Model-observation biases

Catchment – GOES-W Tskin August 2012, 18:00 UTC [K]



Catchment – GOES-E Tskin August 2012, 18:00 UTC [K]

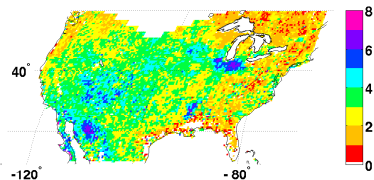


- ▶ Many instances of large model-observations biases
 - ▶ Difficult to determine whether caused by model or observation biases (or both)
- ▶ For assimilation assign the observation-model bias to the observation bias (conservative)
 - ▶ Implemented a dynamic observation bias correction (does not require long data record)

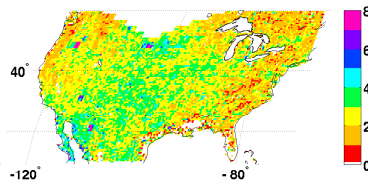
Assimilation results vs. MODIS T_{skin} : Daytime (18UTC)

Anomaly RMSD (K) over JJA 2012

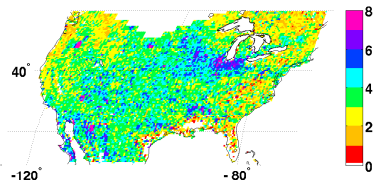
a) Catchment (mean: 2.9 K)



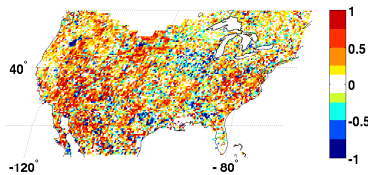
b) GOES-E/W (mean: 2.5 K)



c) GOES-E/W bias corrected to Catch. (mean: 3.5 K)



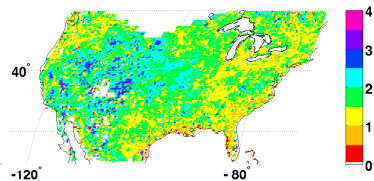
Improvement from assimilation of bias-corrected GOES
(a) - c), mean: 0.15 K, 65% +ve)



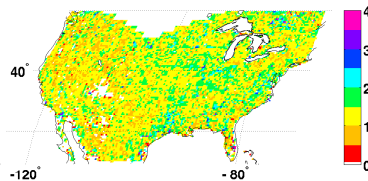
Assimilation results vs. MODIS T_{skin} : Nighttime (06UTC)

Anomaly RMSD (K) over JJA 2012

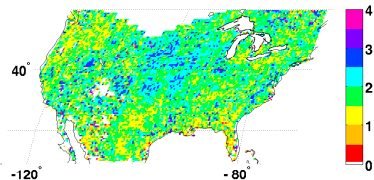
a) Catchment (mean: 1.6 K)



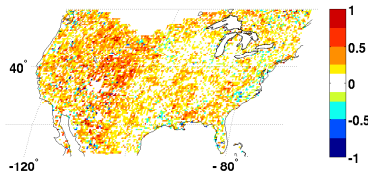
b) GOES-E/W (mean: 1.3 K)



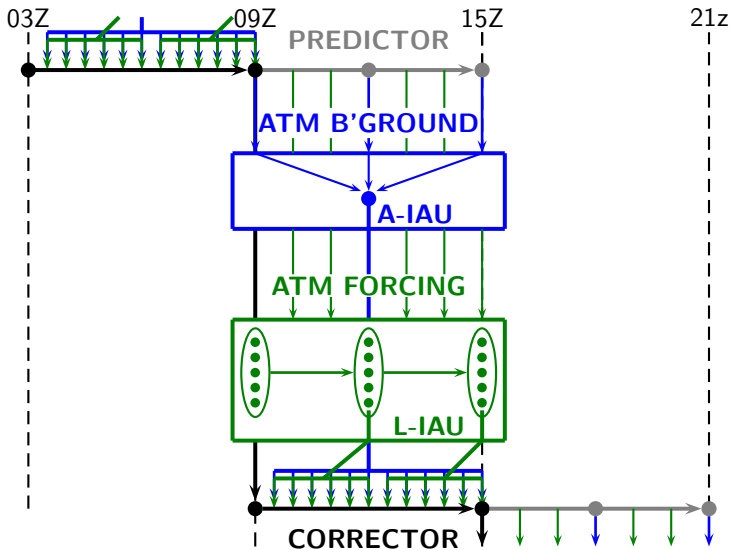
c) GOES-E/W bias corrected to Catch. (mean: 1.8 K)



Improvement from assimilation of bias-corrected GOES
(a) - c), mean: 0.14 K, 78% +ve)



Coupling the GEOS-5 offline L-DAS and A-DAS



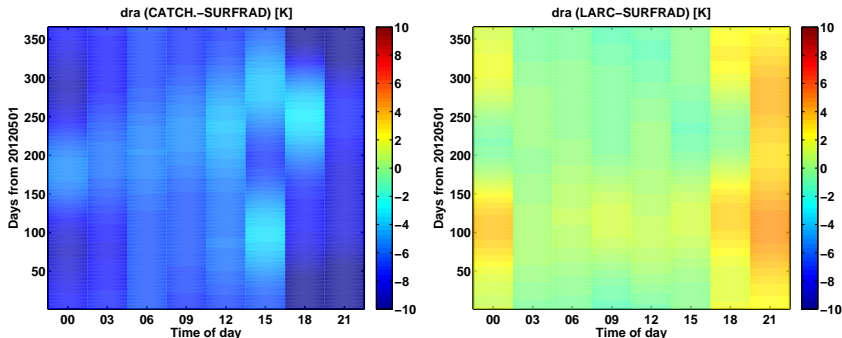
Skin temperature assimilation summary

- ▶ Assimilation of NASA Langley GOES observations improves modeled skin temperature
- ▶ Large model-observation biases address within assimilation using a dynamic bias correction scheme
- ▶ Availability of remotely sensed T_{skin} may also be useful for understanding/improving model performance

THANK YOU FOR LISTENING.

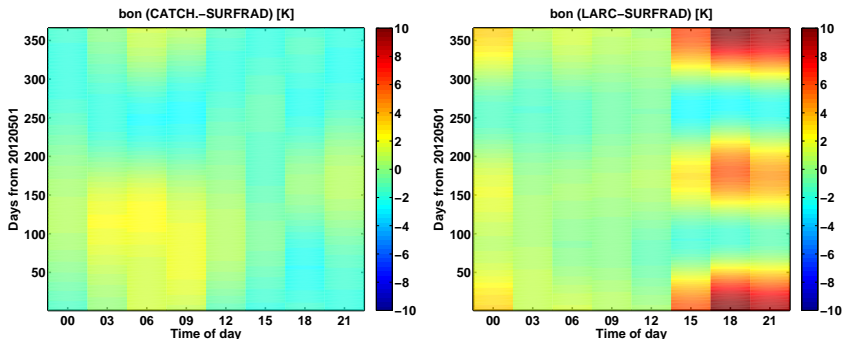
Further details: clara.draper@nasa.gov

Mean difference in seasonal cycle to SURFRAD T_{skin} : Desert Rock, NV



- ▶ Desert Rock SURFRAD observations suggest that large daytime summer Catchment-GOES mean difference in southwest due to cool bias in the Catchment model

Mean difference in seasonal cycle to SURFRAD T_{skin} : Bondville, IL



- SURFRAD observations at other locations do not consistently favor Catchment or GOES mean seasonal cycle